THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION RESEARCH GRANT

NGR-05-020-115

"FIELD INFRARED ANALYSIS OF TERRAIN"

2nd ANNUAL REPORT

1 November 1966 - 31 October 1967

10 December 1967

SECOND ANNUAL REPORT — NGR-05-020-115

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This research performed under NASA Grant NGR-05-020-115.

I. RATE OF EFFORT

A. Analysis of Rate of Effort

This three-year step funded grant has still to run through 1 November 1968. Due to the lack of funding it has been necessary to severely curtail effort. Accordingly only 8.6 man months of effort have been performed over the last six months.

Data reduction of tapes 1 through 21 has continued and two new data tapes were made in the field during the summer period on this project. All aircraft costs and the support of the airborne spectrometer are now borne by the Houston contract NAS9-7313, as well as all costs for laboratory operation. All travel is carried on the MSC contract.

It is most important that this grant be kept as an operational funding system for an additional 12 months as outlined in the original grant document. A major part of the instrumentation which we use in all stages of field and laboratory work was obtained GFE on a facilities grant (NAS2-3402(F)) from NASA-Ames under the conditions that this 3-year step funded grant would be the operating document. Accordingly, whether there is to be any new funding or not for this particular grant, we feel that it should be kept in so that the equipment can still be utilized at Stanford in the many operations of the infrared laboratory.

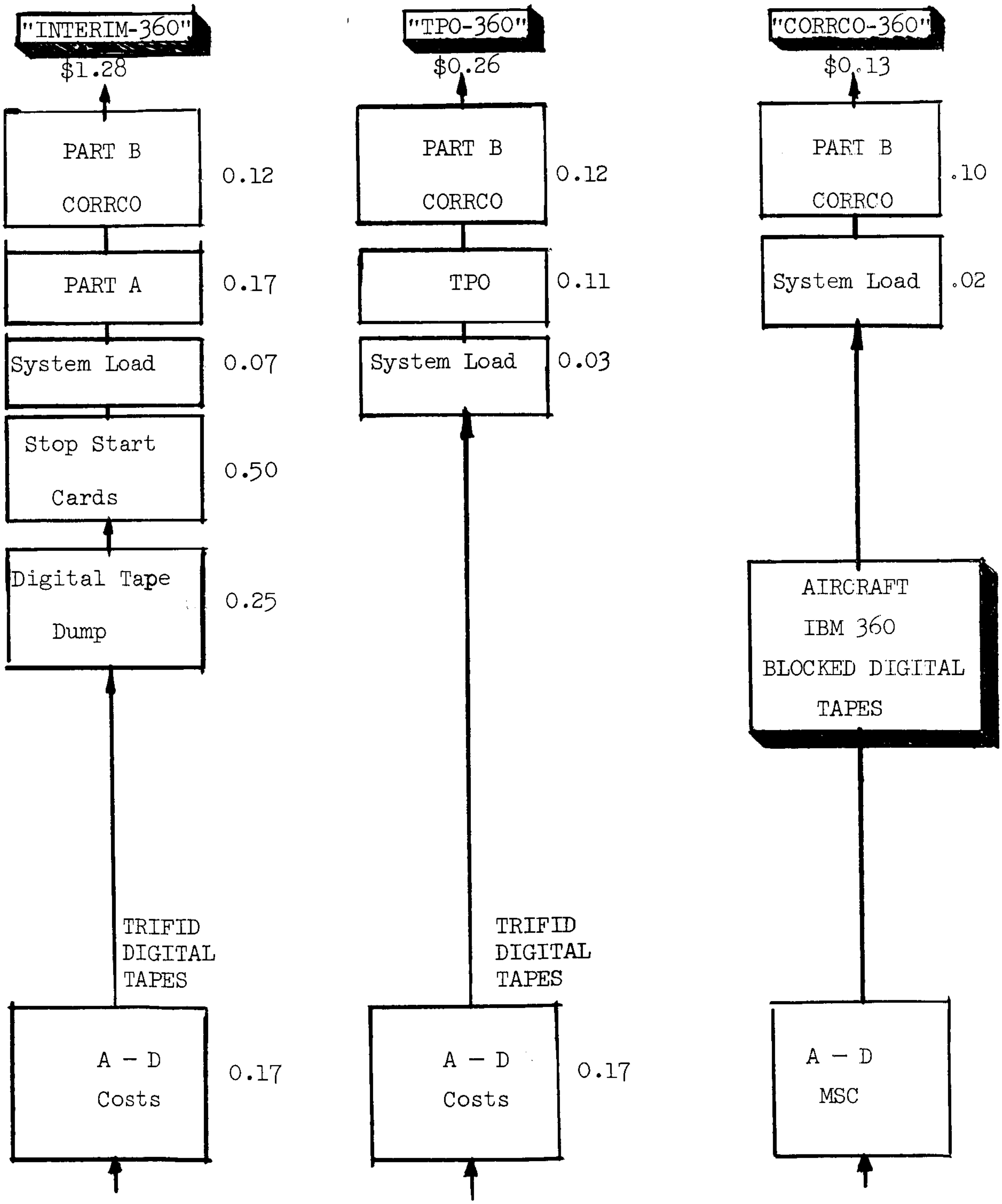
B. Cost Reduction in Data Analysis

Since the last semi-annual report we have considerably shortened the CORRCO programs by more sophisticated programming. This has been somewhat conditioned by the necessity to switch from the IBM 7090 which Stanford sold in September and replaced by an IBM 360. TRIFID digital tapes recorded from early work at NASA-Ames Research Center can now be readily converted to the IBM 360-compatible formats. The new program which has been written (called TPO 360) can read the TRIFID digital tapes directly onto the IBM 360 and produce a 90 point spectrum as its output. Costs have been reduced from an estimated $1.00 to $0.26. The main airborne tapes are reduced by a program called "CORRCO 360" at approximately $0.13 per spectrum.

TABLE I

DATA ANALYSIS COSTS

Data based on 300-500 Spectra/ground Tape



II. GROUND TRUTH - RELATIONSHIP WITH THE STANFORD IR PROGRAM

A conference on ground measurements for the instrument and geologic teams was held on the Reno campus of the University of Nevada March 14-15, 1966. This was an attempt to establish certain test requirements before the field summer season commenced at Sonora Pass.

This two day meeting was designed to identify the basic needs of each instrument group and how these needs might be accomplished. The reader is referred to Tech Letter #3 of the University of Nevada group in which these requirements are fully detailed. Requirements for the IR spectrometer/radiometer experiment have been copied and included in this document as Table II.

Since that time attempts have been made by Stanford and by the University of Nevada to implement as many of these measurements, particularly those dealing with the atmosphere. We have delegated the responsibility to the Nevada group to provide most of the ground truth measurements for the P3A infrared spectrometer/radiometer experiment when this experiment has been used in the airborne mode. At test sites other than Sonora,Mono and Mt. Lassen the ground truth measurements have been made by the Stanford Group themselves.

In a recent study effort at Woods Hole considerable time was spent delineating the basic problems in remote sensing for geology, and methods by which these could best be solved in a research and development effort. Figure 1* is taken from this report and indicates that considerable effort should be devoted to the understanding of the geology of the outermost surface (or "optical depth", "skin depth", or "depth to opacity"). It is this surface skin layer which ultimately determines the response of the rocks to the remote sensors. Detailed study of figure 1 indicates that the maximum effort should be devoted to the surficial geology, with only minor effort devoted to classical geological mapping. A similar minimum effort only should be devoted to the development of new remote sensing hardware. Over 80% of the total R&D effort is recommended be placed in <u>understanding the ground truth data</u>.

* See page 7

TABLE II

PRELIMINARY BASIC REQUIREMENTS AS DEFINED BY DR. R. J. P. LYON FOR THE INFRARED TEAM

MARCH 14, 1966

A. Field Solid or Loose Material -- Surface Only

1. Roughness using Form Tool-NS and EW profiles. Make profile and then record to ± 0.5 mm, by:
   a. Spray paint (not pencil),
   b. Photo sensitive paper (visicorder rolls) on a sheet of rolled chart paper for later reduction by curve follower methods.
   c. Fabric or texture -- describe, draw, and also photograph.
2. Surface sample down to 1 cm depth
   a. If rock, cut 3" x 3" slab and place in cotton in box (mail to Lyon);
   b. If loose, pour black plastic mould for vertical sectioning. Send half to Lyon for modal analysis of polished slab.
   c. Note color, weathering degree, glacial polish, desert varnish, etc. in field.
3. Photometric backscattering in field
   Produce graph at least in N-S and E-W planes. If continuous trace is not available, then position lamp source at +60° and take readings with PE cell at 0, 30, 60, 90, 120, 150, and 180°. (May have to be done after dark if instrument is not adequate.)
4. Emissivity box measurements in field. Two at each grid point. (Need values to ± 0.05.)
5. Color photos vertical. Two each (with original set for Lyon) of:
   a. Kodachrome II or Ektachrome
   b. Aero Infrared Ektachrome (CD)

TABLE II (cont'd)

If possible,

c. From 2 feet and 10 feet

d. Stereo-shifted 3" at 2 feet

e. Stereo-shifted 12" at 10 feet.

Use "b" for Lichen and vegetative counts.

6. Moisture -- if possible in field (especially on flight days)
   a. Surface to 1mm.
   b. Other layer at 1-2 cm depth

   (accuracy needed ± 5% of amount present)

7. Atmospheric -- and micro -- meteorology (especially on flight days). Wind velocity to 1 mph, RH to ± 0.5%. Air temperature (°C) at 1-1/2 meter/ground (to ± 0.2°C), Barometric pressure (to ± 0.05 inches), all taken at a single base-camp with respect to time of day in a 24 hour cycle. Repeated once a week, but specifically performed on flight days 12 hours before to 12 hours after flight. (For colors, use GSA Standard Rock color chart.)

B. Laboratory

1. Modal Analysis, major minerals -- 1500 point count. If fine grained, use thin section(s), if coarser, use a polished slab (+ a thin section to identify the ground mass). Bring piece back for slab polishing.

   Identify:

   a. To ± 1% of amount present -- quartz, K-spar, plagioclase (with An% to ± 5%) pyroxene, amphibole, olivine, mica, glass and voids. Determine bulk rock S.G.
   b. To ± 5% of amount present -- opaques, color index. (Identify opaques if practical.)
   c. Fabric texture, note, preferred orientation of grain pattern in soil using:
      (1) bulk "parent" rock at some small depth below weathering rind and/or soil:
      (2) actual surface chip (or layer of soil) to ± 1 mm depth.

TABLE II (cont'd)

2. Chemical Analysis (X-ray, spec. or emission spec.) Record as oxides to ± 0.5% of amount present. Si, Al, K, Na, Ca, Mg, Fe(T), (+ Fe_2O_3 and FeO if possible). Ti etc. to ± 5% of amount present. Use 1 lb. specimen, pulverize and mix thoroughly. Send 10 grams in bottle to Lyon. Get powder SG as well as bulk rock SG.

R & D EFFORT MIX RECOMMENDED

FOR REMOTE SENSING IN GEOLOGY

		EFFORT IN LAB	EFFORT IN FIELD	DATA FROM AEROSPACE	%
INTERPRETATION	Classical Geology	2%	2%	2%	6
	Surficial Geology*	6%	15% A	12% B	33
	Inter-Relating Remote Sensing Data to Surficial Geology	15% A	15% A	12% B	42
HARDWARE	Remote Sensing Technology and Hardware	4%	8%	7%	19
		27	40	33	100

A,B implies a time-step sequence

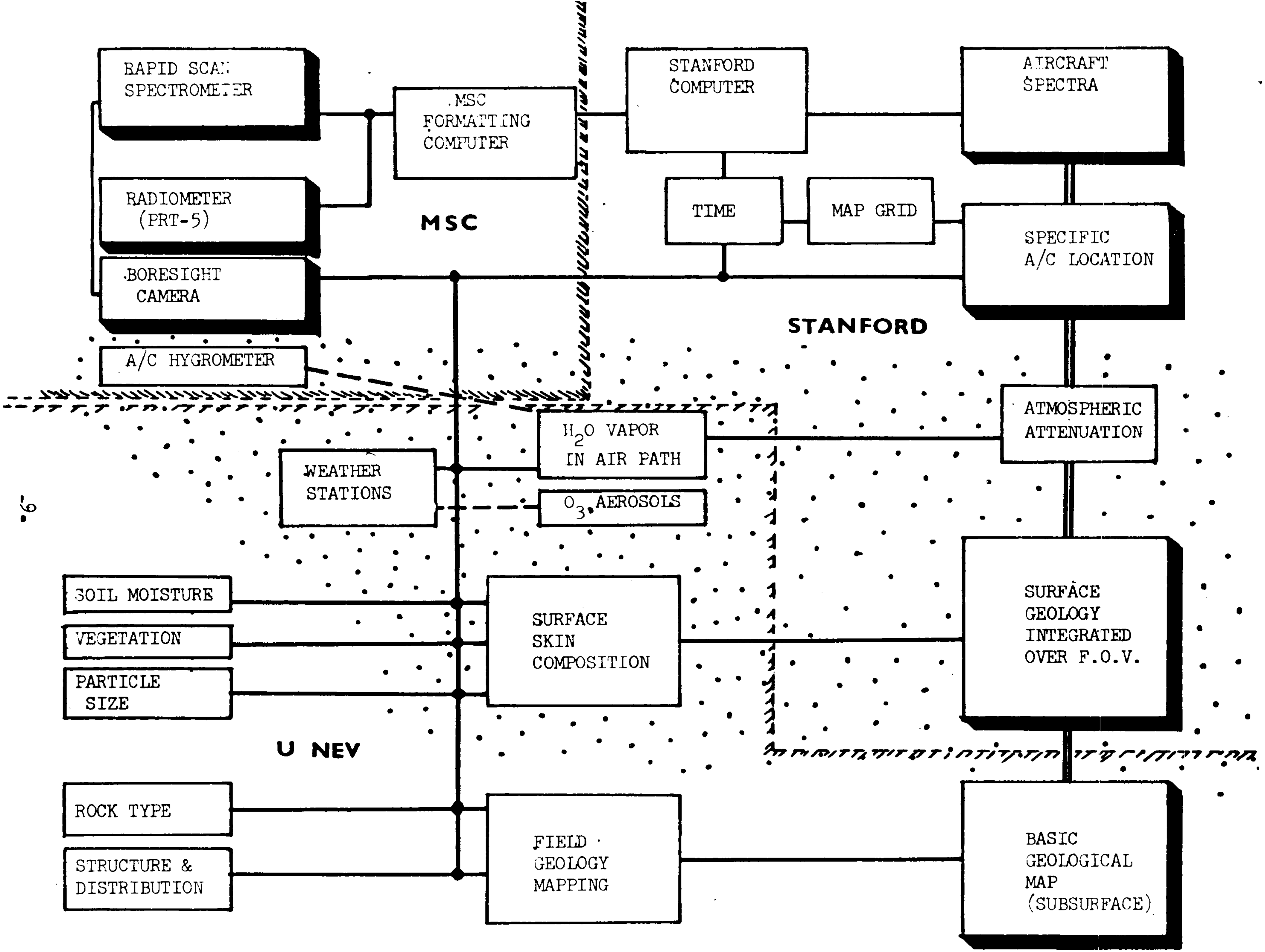
*Surficial Geology = "Optical Depth", "depth to opacity", "skin depth", generally $\frac{\lambda}{10}$, to 10 λ.

In order to relate these concepts to the operational aspects of the P3A aircraft figure 2 has been drawn. In this flow diagram the relationships between Stanford, University of Nevada and MSC on the infrared spectrometer/radiometer experiment are clearly indicated. The stippled areas in the center of the diagram are those in which much more research and many more measurements are required.

In the top left-hand corner of figure 2 in the hachured area is shown the area of responsibility of MSC, for operational use of the combined package (the Rapid Scan spectrometer, the radiometer (or PRT-5), the boresight camera, the aircraft hygrometer and the aircraft data recording system). The next block indicates that the data from such an aircraft operation flows through the MSC formatting computer to produce blocked digital tapes immediately compatible with the Stanford IBM 360 computer system. The boresight and RC8 camera data are sent to Stanford to establish the precise ground position of the aircraft at any given time (needed to $\pm$ 10 feet at 2000 feet). These data are used in an interpolation program in the Stanford computer to establish the aircraft position on an arbitrary ground grid, which is drawn on a base map prepared from high altitude photographs of the locality, taken (hopefully) the same day. From these two outputs it is possible to relate any given time (as from the ASQ90 or from the various aircraft clock systems in use at the moment) to a portion of the map grid, and hence (through the relationship shown as a vertical line) with the mapping and ground truth parameters determined by the University of Nevada.

The identification of aircraft location on high altitude photographs and on the map grid, as well as the production of the computer reduced aircraft spectra and all data analysis are the responsibilities of Stanford University. In the lower section in the left-hand and bottom edge of figure 2, the responsibility areas of the University of Nevada are indicated.

In the center of the diagram the attenuation of the emitted infrared radiation by the atmospheric column is measured, by the use of weather stations, and, when used together with the aircraft hygrometer, provide a profile of the water vapor in the airpath between ground and



STANFORD/U.NEVADA/MSC RELATIONSHIP ON INFRARED SPECTROMETER EXPERIMENT --P 3A AIRCRAFT.
STIPPLED AREAS NEED MUCH MORE ATTENTION.

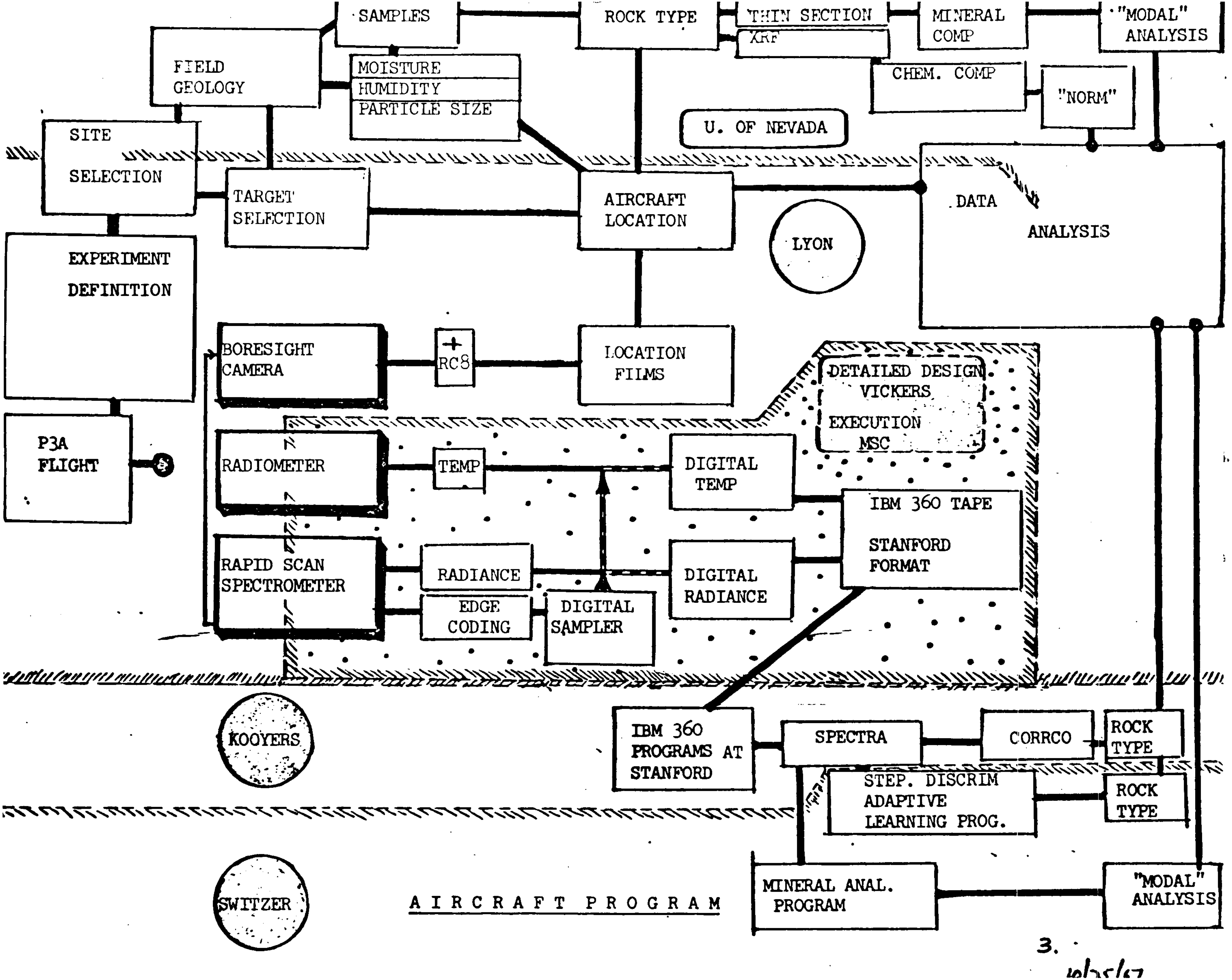
2.

aircraft for the computers at Stanford. The field data collection is well in hand but the aircraft systems need improvement. The second block (Surface Skin Compositions) is determined by measurements of soil moisture, vegetation count and particle size. These surface skin compositions are then related (through the aircraft time system) to surface geology (along the aircraft track) integrated over the field of view of the equipment (0.3°) at any one instant of time. This is one of the major ground truth measurements which must be made in greater detail than is in present practice.

The lower section of figure 2 shows how determination of rock type and the pattern (or structure) and distribution of rock types are related through field geology mapping to a basic geological map. A typical geological map is a subsurface map and generally does not show, for example, the position of snow banks, sand dunes, and other surficial cover. These all affect the "target", which is the surface integrated over a field of view of the instruments. The vertical time-linkage between the University of Nevada operations and the MSC operations of the aircraft is essential (and will be brough out in a later chart) as ground truth is only useful where the aircraft passed in its flight pattern.

A more detailed analysis and flow chart of the operation is shown in Fig. 3. This rather complicated diagram starts in the center left-hand side with an Experiment Definition, a Site Selection and a specific Target Selection, which were confirmed at the pre-flight Mission Briefing approximately 14 days before the flight. The P3A flight then occurs and starts the flow diagram into operation.

In the center of the diagram one sees the boresight camera being triggered by output from the spectrometer and their mutual relationship with the radiometer (presently the PRT-5). The aerial cameras give the aircraft location. These locations are compared then with the target selections and the ground truth measurements made by the University of Nevada. The area of responsibility for the Nevada group is shown in the upper hachured segment. Laboratory work, following the aircraft flight will enable the University of Nevada to prepare Rock Type analyses



AIRCRAFT PROGRAM

using thin section and point counting and to provide Stanford with a modal (or mineralogical) analysis. The x-ray fluorescence unit yields a chemical composition of the rocks from which one can determine a "normative" or theoretical mineral composition. Both of these analyses are fed into the block labeled "Data Analysis". Again it is most important that the samples used in the determination of the rock type and chemical composition be those which are exactly (or at least adequately represented) along the flight lines actually flown.

In the center panel we see the relationships between the aircraft operation at MSC and the data handling design responsibilities of Stanford (under Dr. Roger Vickers). The center hachured and stippled area shows the detailed experimental design (which originated at Stanford) and its execution in an aircraft flight and subsequent data reduction performed at MSC. Digital recording is still not installed in the aircraft although we are already installing it for our ground operations. The digital radiometer and spectrometer outputs are sampled in the computer by the signal from the edge coding around the periphery of the filterwheel in the spectrometer. This pulsed signal is used to trigger the digital sampler in the computer. This in turn produces an IBM 360 tape formatted to the Stanford pattern. This tape is then sent to Stanford wherein spectra are produced from programs operating on the Stanford computer.

These spectra are the single most important product of the entire flight. An on-line program called CORRCO (a correlation coefficient program, see SRSL Tech Report 67-1) is used, and this produces a ranked, rock type analysis as seen on the right-hand side. Other Stanford programs are used by Switzer in a step-wise discriminant function (or adaptive learning) program which learns from standard spectra and identifies rock classes on a probability basis. The correct class is assigned to each incoming aircraft spectra. Another rock type listing is produced and this, in turn, is compared with the CORRCO rock type ranking, in the Data Analysis block. A further program is utilized by Switzer at Stanford in the mineral analysis program to produce a "modal" (or mineralogical) analysis as its end product. This also is compared through the Data Analysis block with that derived by rock type analysis by the University of Nevada.

This is the program design diagram. At present few of the cycles have been completed for Mission 56 as considerable portions of the data are not yet available. Modal analyses of thin section material have not yet been prepared but a number of useful chemical compositions and normative analyses have been received. These however are percentages of theoretical minerals and not the actual minerals occurring in the rock. In addition, most of the samples which have been so far analyzed are not from this year's flight lines. This is not meant as a negative statement, but to indicate work yet to be done on one mission. We are all in a learning situation with "ground truth", and working responsibilities and tasks are continually becoming more clearly defined.

In the area represented by the center block called "Aircraft Location" we have also had many problems due to the malfunction of the boresight camera. We have had to revert to an aircraft location method which utilizes the RC8 cameras which trigger every five seconds. These cameras carry their own clocks and it is possible with a fair degree of precision* to interpolate spectral start times between individual RC8 frames to locate the 300 spectra which occur between each RC8 photograph. The RC8 cameras were locked in position to the aircraft frame and were not corrected for drift in order to have them record as accurately as possible the nadir beneath the line of sight of the spectrometer.

In summary some points to be made are shown in Table II B as a listing of axioms for ground truth operations. These are:

1. Ground truth data are only useful along the aircraft ground track.
2. Weather data is only useful at flight time.
3. Water content in the air and on the ground is the single most important parameter to be measured.
4. Ground truth data are only useful if they can be used in subsequent statistical analysis of the data.

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*($\pm$ 25 feet). 180 Kts. = 300 feet/sec. FOV of spectrometer is 0.3° or 5 m radians, or 10 feet at 2000' clearance. A/C smear is 50 feet in the 150 msec between spectra totalling 10 x 60 feet/spectrum.

TABLE IIB

AXIOMS FOR GROUND TRUTH

1. GROUND DATA ONLY USEFUL WHERE THE AIRCRAFT ACTUALLY WENT. THIS MAY NECESSITATE POST-FLIGHT GEOLOGY AND SAMPLING. THIS IS PARTICULARLY SIGNIFICANT FOR NON-IMAGING LINE-TRACE EQUIPMENT LIKE IR SPECTROMETER, RADIOMETER AND MICROWAVE RADIOMETERS.

2. WEATHER DATA IS ONLY USEFUL AT FLIGHT TIME AND FOR 24 HOURS PRIOR TO FLIGHT IF GROUND IS WET.

3. WATER CONTENT IS THE SINGLE MOST IMPORTANT PARAMETER TO BE MEASURED BECAUSE OF ITS HIGH ABSORPTION COEFFICIENT AND EFFECT IN THE DIELECTRIC CONSTANT.
   A. MOISTURE ON GROUND
   B. MOISTURE DOWN TO SKIN DEPTH, $f(\lambda)$
   C. WATER VAPOR IN TOTAL AIR PATH FOR IR, AND ITS DISTRIBUTION WITH TIME
   D. LIQUID WATER DROPLET SIZE AND FREQUENCY IN AIR PATH FOR MICROWAVE AND RADAR WAVELENGTHS

4. GROUND TRUTH DATA ARE ONLY USEFUL IF THEY CAN BE USED.

In conclusion, it is still necessary at present to make a considerable number of ground truth measurements. It is perhaps debatable how many should be made prior to aircraft flight, during aircraft flight or following the aircraft flight. In some cases the seasonal conditions preclude making these measurements after aircraft flight, particularly when one considers the time required between the aircraft flight and receipt of the photographic data by which aircraft tracking must be determined. One must then add time for a considerable amount of work involved in transferring camera center points from the RC8 camera and in locating these on the ground. It can be estimated that approximately 2-4 weeks effort would be required after an aircraft flight and prior to accurate ground location being obtained along the aircraft track.

We must more fully understand the total system, how the ground truth parameters and the subsurface geology (as shown on a typical geological map) interact in the surficial skin geology, and in turn how the atmosphere between the aircraft modified these signals. We must not neglect the effects of the aircraft data system and how final output from the computers further changes the data. After all "success" is the right relationship between the output from the computers and the final output from the ground truth measurements. Before this becomes possible we are going to have to face up to the collection of a considerable amount of possibly redundant data. In addition a strong plea must be made for more sophisticated ground measurement systems. It is already fairly clear that even measurement of water vapor content between an aircraft and the ground is an extremely difficult and quite sophisticated meteorological experiment, not yet performed by meteorologists with a degree of local and temporal precision requested by this experiment.

III. COMPUTER PROGRAMS - STATUS, CHANGES AND UPDATINGS

A. CORRCO-360 - Replaces "INTERIM 360" and "NSCP"Programs

As a part of our continual up-grading of computer programs at Stanford University, and also because of the conversion of the computer facility from the IBM 7090 to the IBM 360 equipment, it has become necessary to change most of our programming over the past summer period. Accordingly we have now developed a main-line program (or main aircraft program) called CORRCO 360. This again emphasizes our general thesis that a single program should be capable of receiving data from several spectrometers.

The CORRCO 360 program is based on a format statement requiring a pre-determined 90 point spectra at fixed $\Delta\lambda$ intervals. With the filter-wheel spectrometer in the P3A aircraft these 90 points are determined from output pulses at every 2° of rotation of the wheel. In the TPO-360 program for ground data these 90 points are determined at 90 evenly spaced $\Delta\lambda$ intervals between the start wavelength and stop wavelengths.

CORRCO therefore replaced INTERIM 360, as well as the Lockheed system (called NSCP when on the Stanford computers).

Several options are available including the ability to insert "foreign" spectra by use of an "Entry Point B". With this it is possible to digitize any analog spectrom to these same 90 wavelength points, and then enter the CORRCO 360 program for correlation coefficient at a late stage*. The output is formatted in a similar manner and character to that of any other of the aircraft or ground spectra. CORCCO 360 program can read the digital tapes sent from MSC Houston, which are now formatted to the Stanford IBM 360 format. This has been discussed in great detail in previous monthly reports on NASA contract NAS9-7313.

*See SRSL Tech Report 67-3 (issued November 1967) for usage of this concept on the 13 USGS spectra in their Tech Letter #13.

B. "INTERIM-360" Program for Card Input - Entry Point B
(Now outdated at Stanford but included for information of users with an IBM 7090. The basic logic remains the same even in the CORRCO 360 package.)

1. Identification:

NSCP2B - Spectral correlation program for card input (see Remote Sensing Laboratory reports (67-1, 67-2) for details of the spectral correlation program.)

2. Purpose:

NSCP2B calculates correlation coefficients between spectra input on cards and a library of spectra. The library spectra are ranked from highest to lowest correlation with the input spectra.

3. Method:

The emittance ratios of a spectrum at several discrete wavelengths are considered to be independent observations. Means, standard deviations, etc., between the input spectrum and each library spectrum.

4. Usage:

The first-time the program is used the library spectra are input on cards. The library is stored on magnetic tape in binary modes. Thus in any subsequent use of the program with the same library, the library may be read from magnetic tape with a saving in computer time.

a. Input data formats:

Card Set 1

Card 1 (4F 10.5)

Col 1-10	NEWLIB	(use floating point numbers, i.e., 1.0)
Col 11-20	NUMLIB	
Col 21-30	NSPCPT	
Col 31-40	NLIBLT	

NEWLIB = 0.0 a blank library to be read in off tape

$\neq$ 0.0 library to be read from cards.

NUMBLIB = number of lib spectra to be read in. (may be left blank if library is to be read from tape.)

NSCPCPT = number of spectral points per spectrum (may be left blank if library is to be read from tape)

NLIBLT = 0 No listing of the library is generated

≠ a listing of the library is generated (a listing of the library is always generated when the library is read from cards).

Card Set 2

Card set 2 is not required when the library is read from tape)
Card set 2 is repeated NUMLIB times. Corresponding to the number of library spectra.

Card 1 (12A6)

Col. 1 to 72 tape title in BCD

Card 2 (6X, 6A6)

Col 1 to 6 ignored

Col 7 to 36 library spectrum title in BCD

Col 37 to 42 library spectrum symbol in BCD
(i.e. MYRITE for meteorite)

Card 3 to 4 + NSPCPT (IX, 2F 6.2)

Col 1 ignored

Col 2 to 7 wavelength (i.e., 7.80)

Col 8 to 13 emittance ratio (i.e., 0.792)

Card 3 + NSPCPT + 1 (12 Ab)

This card is ignored. Usually this card says END OF SPECTRUM

Card Set 3 (input wavelength cards)

Card 1 (F10.S)

Col 1 to 10 NPTS - the number of spectral points in the spectra to follow.

Cards 2 to (NPTS/7) + 1

Col 1 to 10 LAMA(1) wavelength of first spectral point

Col 11 to 20 LAMA(2) wavelength of several spectral point, etc.

Card 3 contains LAMA(8) to LAMA(15)

use as many cards as are needed

Card Set 4 (Input Spectra Cards)

Card 1 (2A6, 7X, A6, IX, AS, IX, 8A6)

Col 1 to 12 CT type of spectra to be processed

CT must be one of the following:

EMITTANCE bbb (b stands for blank)

EMIT. b RATIO b

BLACK b BODY bb

b b b b b b b b b b b b

Col 13 to 19 ignored

Col 20 to 25 BC(1) spectrum symbol in BCD

Col 26 ignored

Col 27 to 31 BC(2) Spectrum number (i.e., 905A)

Col 32 ignored

Col 33 to 80 BC(3) to BC(10) spectrum title and comments

Card 2 to (NPTS/7) + 1(7F10.5)

Col 1 to 10 E(1) or ER(1)

If EMITTANCE was specified on Card 1 of card set 4 then data should be emittance. If EMIT.RATIO was specified then ratio data should be used.

Col 11 to 20 E(2) or ER(2)

etc. for the rest of the card. Use as many cards as required with seven emittance or emittance ratio values per card.

b. NOTE 1: if BLACKBODY is specified then this blackbody spectrum is averaged with the immediately following blackbodies. The program expects EMITTANCE cards after BLACKBODY Cards. The program then computes emittance ratios and outputs emittance ratio cards.

c. NOTE 2: If a blank card is used or if neither EMITTANCE EMIT. b RATIØ, or BLACK b BODY bb is specified the program is terminated.

(b = 1 blank space; bb = 2, etc.)

C. CARD CHECK PROGRAM

1. PURPOSE - To check input stop-start time data card to NSCP

2. USAGE - Starts the start-stop time cards behind green card as they are to be run with NSCP.
If more than one set is to be run sequentially then insert a card with * in col. 22 and 23 and blanks in col. 24 to col. 27 between the two sets.

3. OUTPUT - A listing of the information on the input cards is provided. Delta is also calculated and printed out. Delta is the time between data samples.

Whenever an error in the input data occurs the message ERROR IN SPECIFICATIONS is printed out.

4. PROGRAM - The program checks for the following

   1. Start time less than previous start time
   2. Stop time less than previous stop time
   3. Stop time less than start time
   4. DELTA greater than twice the average of previous DELTA'S
   5. DELTA less than half the average of previous DELTA's

D. INSTRUCTIONS FOR GENERATING TAPE INDICATIVES ON TRIFID TAPES.

1. Definitions:

bit - one binary character either 1 or 0

byte - 6 binary characters (one byte is read from a magnetic tape when the tape is advanced the smallest possible amount). The binary characters are read from the 6 tracks on the tape. (A seventh track is used for a parity check).

word - 6 consecutive bytes. This constitutes the smallest amount of information read into the 7090 computer and occupies one "word" of 7090 storage.

physical record - 256 words. The TRIFID tapes are blocked such that a 3/4" gap (no recorded information) exists between each 256 words of information.

The first record of a file of TRIFID tape information must contain the following information.

a. The first two words (12 bytes) of the first record consist of anything which will serve as identification information. For example, tape 7 (Lyon designation) has the identification of an octal 7 in the 12th byte. All other bytes are zero. Thus the first word of the record consists of zero, and the second word of the record consists of 7.

b. The third word of the first record consists of 1. Thus bytes 13 to 17 are zero and byte 18 is 1.

c. The fourth word of the first record consists of 2. Thus bytes 19 to 23 are zero and byte 24 is 2.

d. The fifth word of the first record consists of zero. Thus bytes 25 to 32 are all zero.

e. The remainder of the 256 words are usually filled with zero; however, word 256 may contain the range coded time. This is optional.

The following is additional information if sometime it will be desirable to use more than two channels of data.

f. If more than two channels of data are recorded on the TRIFID tape, then a 3 is placed in word 5 and a 4 in word 6 and so on.

g. A sync bit (negative sign) must be placed in the first channel information e.g. for a wavelength and emittance 2 channel tape, the wavelength is always written with a negative sign. If more than two channels are to be written then the negative bit is placed only in the wavelength channel. For the case of dual channel information, if the indicatives are specified in error the NSCP computer program will "flip" the indicatives making 1 a 2 and 2 a 1; however, when more than two channels are used, the value in the third word (first indicative) must be the number of channels to the sync channel in the first words of the second record. E.g., if wavelength starts off the data and contains the sync bit, and occurs first in the flow of data, that is the first two bytes of the second and subsequent records are wavelength, then the first tape indicative (third word of the first record) is a one. Otherwise, if the sync bit occurs in any other channel in the data, the tape indicative consists of the number of bytes to the first sync bit in the record divided by two. Subsequent tape indicatives increase by one for each word until the total number of channels has been reached then the next indicative is one, the next two and so on.

E. TRIFID TAPE FORMAT(prepared by Lockheed Missile & Space Co.(Sunnyvale)

1. PURPOSE

The purpose of this procedure is to familiarize the Data Processing and Analysis personnel with the TRIFID Tape Format.

2. DESCRIPTION

a. For general tape information refer to SRSL Tech Report 67-1, 67-2.

b. Data records may contain up to 255 words followed by one word of time.

c. Data words are in Counts: $0 \leq \text{Counts} \leq 2047$.

d. Up to eight continuous parameters may be merged together on one file. The actual record length of a given file will be determined by the number of data sets (one data word for each merged parameter) that may be written in a record containing up to 256 words, including coded time. The following table indicates the various record possibilities.

No. of Parameters	Data Words/Rec.	Data Samples/Rec.	Data Sets/Rec.
1	255	765	765
2	254	762	381
3	255	765	255
4	252	756	189
5	255	765	153
6	252	756	126
7	252	756	108
8	248	744	93

e. Each computer word contains three data quantities as shown in the following illustration.

BITS	1	12	13	24	25	36
	S	DATA WORD	S	DATA WORD	S	DATA WORD

S = Sync Bit = A one bit in this position indicates the first quantity in the merged set.

Following the computer data words the last word of the record will be one of the following time words:

RANGE CODED TIME

IBM Sign Bit

	HOURS		MINUTES		SECONDS				
BITS	1	4	5 8	9 12	13 16	17 20	21 24	25 28	29 32	33 36
	Tens		Units	Units	Tens	Units			
						Tenths	Hundredths	Thousandths	

ACCUMULATED BINARY CODED TIME WORD

IBM Sign Bit

1	ALL ZEROS	24 BINARY TIME 1
		MSB LSB

MSB = Most Significant Bit

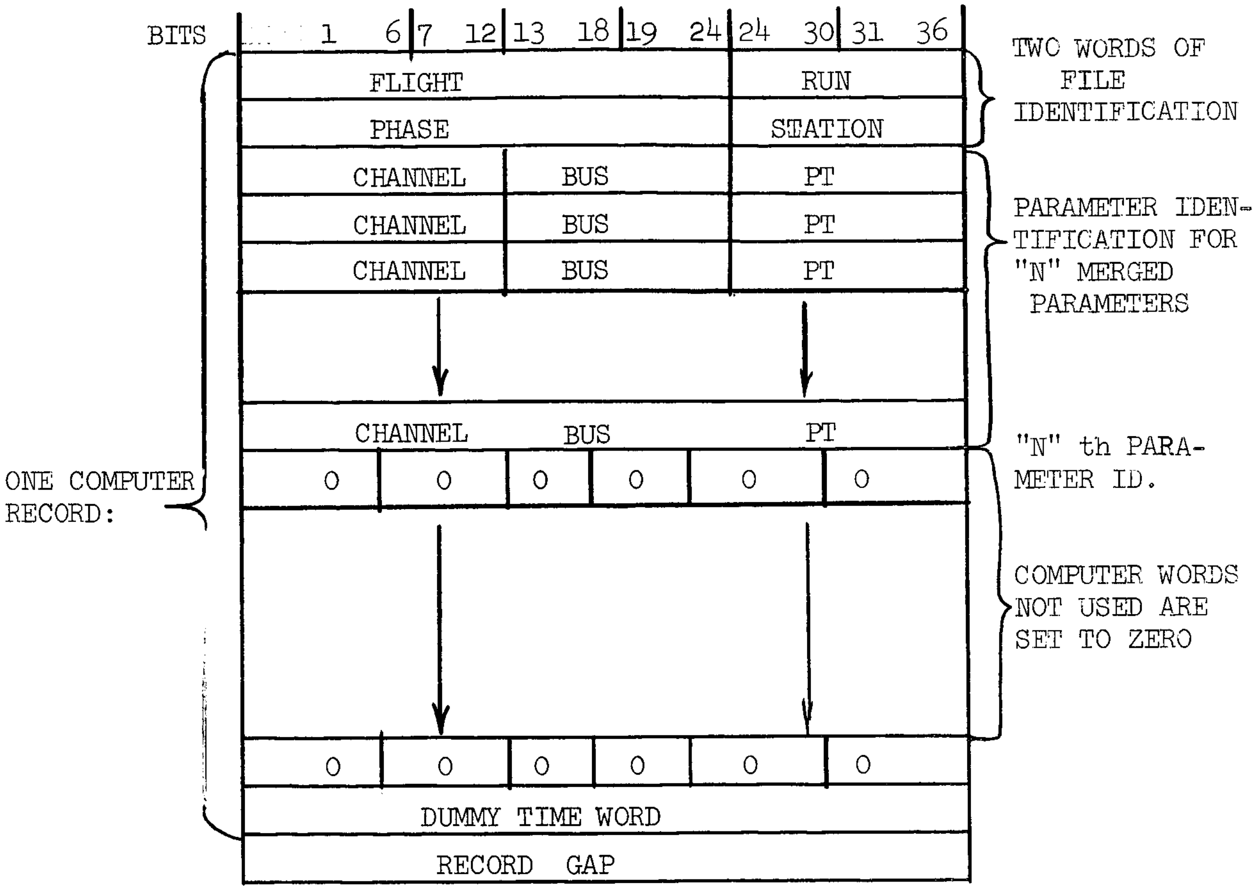
LSB = Least Significant Bit

f. The presence of a one (1) in the IBM sign position indicates accumulated rather than range coded time.

g. The normal time base for accumulated time words will be 10 KC, but other frequencies may be used. (100 KC MAX)

h. The time between data samples within a multiplexed set is a constant (25 microseconds)...

i. The first record of each file will contain the indicatives for all the parameters in the file. The indicative record will contain two words of file identification and one word identifying each parameter merged in the file. See the following illustration of the indicative record.



F. <u>Computer Programming Effort Level</u>

<u>Program Descriptions:</u>

CORRCO 360 - Main line program (= main aircraft program).Requires a predetermined format of a 90-point spectrum at $\Delta\lambda$ intervals. These are at every 2° of rotation of the aircraft CVF wheel, or 90 $(\text{even} - \Delta\lambda)$ intervals from TPO. This is an updating of the "INTERIM 360" program.

TPO 360 - Ground data program. Reads TRIFID format digital tapes and selects spectra by finding wavelength turnaround points using first and second derivative of λ ramp voltages. Feeds directly into CORRCO-360 by generating a 90-point spectrum at equal-Δλ intervals between START and STOP wavelengths.

TPT - Similar to TPO, but reads wavelength from encoder pulses on a third track of the analog tape. Wavelength ramp voltages are not used at all, but λ values are assigned to the encoder pulses. Programming not fully completed. Only tape 21 is recorded with this encoder pulse.

INTERIM-360 - Now replaced by CORRCO 360.

ALLOCATION OF EFFORT - PROGRAMMING

TPO 360	1067	43%
OLD TAPES	335	13
A/C MISSION 56	260	11
STAT. PROGRAMS	180	9
7090-360 CONVERSION	160	6
TPT	138	5
CORRCO	110	4
	$ 2250	

TAPES 1-16	1602	65%
TAPES 17-21	348	14
MAIN A/C PROGRAM (MISSION 56)	300	11
	$2250	

III.G STATUS OF STANFORD TAPE RECORDS

The attached table (Table III) lists the detailed status of the Stanford tape records prepared over the past 2-1/2 years of operation. In many cases these tapes are of insufficient quality to be more fully reduced and will have to be stored until more sophisticated systems of data analysis are available. A priority listing has been established in which the tapes will be reduced with the first priority being assigned to the aircraft tapes of Padres Island and Mission 56. The second priority listing is given to tape 11 (which is in its final stage of processing), followed by tapes 21, 17 and 16 in that order.

Several principal sources of problems exist for the Stanford tapes. Firstly, it has been found that the spectra recorded on any of the SG-4 instruments (either the Stanford unit or the Huntsville units) show a definite difference between spectra recorded on the upward ramp and the downward ramp. It has been necessary therefore to program the computer in such a manner that these two sets of consecutive tape recordings of spectra are segregated, and that only up-ramp samples are compared with up-ramp libraries and down-ramp samples with down-ramp libraries during data reduction process. This is now a normal output of the TPO-360 program on the IBM 360 at Stanford.

A second cause is the the low signal to noise ratio on the original recording. This has come about in the following several ways.

1. Low signal due to the use of a thermistor instead of a Cu:Ge cooled detector.
2. Low signal (due to a degraded Cu:Ge detector) due to insufficient cooling with liquid helium or the dewar being tilted at too high an angle.
3. High noise due to a microphonic Cu:Ge detector.
4. High noise due to operation of the Citizens Band radios and other electronic equipment in close proximity to the recording system.

In addition, other problems were caused by:

5. A tape recorder VCO drift which ensured a total lack of determination of the true wavelength at any time and
6. Poor tape speed compensation (prior to tape 11). After tape 11 a crystal-controlled frequency of 12-1/2 KC was permanently installed in the spectrometer.

All these effects have interacted to produce a series of tapes of varying degrees of perfection. It is therefore necessary to establish a tape reduction priority based upon a) geological significance and b) S/N ratios by which our somewhat meager funds can be used to their best advantage. This is in continuing revision and the status of the tapes will change as a function of time and the effort which is available to be placed in their reduction.

No further tapes will be made on the analog recording system using the SP300 and the with the spectrometers in their analog output condition.

A digital recording system is now installed, the A-D step of which is triggered by pulses at pre-determined wavelength from a shaft-encoding system on the SG-4, or a peripheral, edge-coding system on the circular variable filters in the Stanford CVF system or on the P3A aircraft system. In future only digital recordings will be made at Stanford in the laboratory or in the field and the analog systems will be phased out permanently.

TABLE III

STATUS OF STANFORD TAPE RECORDS

FIELD TAPE NO.	PRIORITY	RECORDED BY	MONTHS SINCE RECORDING	A – D CONVERSION MADE	A – D QUALITY	COMPUTER RUNS MADE	HOLD UP	PROGRAM TO BE USED	REDUCTION OUTLOOK	COMPLETION DATE
				STANFORD TAPES						
11*	2A	Patterson/ Lyon	17	Yes	Good	23	Library(VEG.)	TPO	Good	1/1/65
21	2B	Vickers	3	No	---	---	#17 Success (& A–D)	TPT/TPO	(ENCODER)	
17	2C	Vickers	10	3 times	Poor	---	A–D(12/1/67)	TPO		
16	2D	Vickers	14	No	---	---	#13 (& A–D)	TPT/TPO	Thermistor	
12*	3A	Patterson/ Vickers	14	No	---	---	Tape Quality	TPO	?12/30/67	
19	3B	Vickers	9	No	---	---	#17 Success (& A–D)	TPO	-----	
20	3C	Vickers	9	No	---	---	#17 Success (& A–D)	TPO	-----	
6B	3D	Patterson	25	Yes	Good	2**	#11 Success	TPO	Good	
7B	3E	Patterson	25	Yes	Good	2**	#11 Success	TPO	Good	
13	3F	Patterson/ Vickers	14	No	---	---	Tape Quality	TPT/TPO	Thermistor	
14	3G	Patterson/ Vickers	14	No	---	---	Tape Quality	TPT/TPO	Thermistor	
15	3H	Patterson/ Vickers	14	No	---	---	Tape Quality	TPT/TPO	Thermistor	

TABLE III (cont'd)

NASA/ARC — LMSC TAPES

FIELD TAPE NO.	PRIORITY	RECORDED BY	MONTHS SINCE RECORDING	A — D CONVERSION MADE	A — D QUALITY	COMPUTER RUNS MADE	HOLD UP	PROGRAM TO BE USED	REDUCTION OUTLOOK	COMPLETION DATE
4	4A	Patterson	25	Yes	Fair	6**	Tape Quality	TPO	----	
9	4B	Patterson	24	Yes	Fair	6**	Tape Quality	TPO	----	
10	4C	Patterson	24	Yes	Fair	5**	Tape Quality	TPO	----	
8	4D	Patterson	24	Yes	Fair	3**	Tape Quality	TPO	----	
6A	--	Patterson	25	Yes	Poor	2**	Bad A — D	LMSC	----	
7A	--	Patterson	25	Yes	Poor	5**	Bad A — D	LMSC	----	
5	5A	Patterson	25	Yes (No longer available)		1 (LMSC)	Tape Quality (& A–D)	---		
3	5B	Patterson	25	Yes (No longer available)		2 (LMSC)	Tape Quality (& A–D)	---		
1	5C	Patterson	27	Yes (No longer available)		1 (LMSC)	Tape Quality (& A–D)	---		
2	5D	Patterson	27	Yes (No longer available)		1 (LMSC)	Tape Quality (& A–D)	---		
18	Not Recorded									

* Short Wavelength (0.7 — 4.0 μ) SPECTRA

** Computer Runs used "Interim 360" or "LMSC" Programs

TAPES RECORDED FM, $13\frac{1}{2}$ KC CENTER FREQUENCY ON AN AMPEX SP300, 7-CHANNEL RECORDER. A $12\frac{1}{2}$ KC SIGNAL IS ALSO RECORDED TO PROVIDE TAPE SPEED COMPENSATION.

IV. RESULTS FROM COMPUTER PROCESSING

A. Up-ramp and Down-ramp Spectral Difference

Inspection of the computer output for tapes 6B and 7B (newly re-digitised equivalents of the noisy 6A and 7A) showed an alternating pattern of success and failure in correlating successive spectra with correct rocks in the library. Tape 7B was more clear than 6B in this regard and the following table shows the detailed results if the spectra are segregated.

TABLE IV

	Tape 7B		Tape 6B	
CORRCO RANKING (out of 19)	UP RAMP (λ increasing)	DOWN RAMP (λ decreasing)	UP RAMP (λ increasing)	DOWN RAMP (λ decreasing)
VERY GOOD (1st or 2nd choice correct)	78%	33%	28%	22%
FAIR (Correct choice is first five)	2%	15%	25%	18%
WRONG (Clearly a misidentification)	20%	52%	47%	60%

This further emphasizes a problem we have had for some time with the SG-4 data -- that of non-symmetry of grating drive. We have now redone the programming and spectra are segregated at an early stage before ratios are taken to obtain emittance ratios. The blackbodies are segregated as well and a much more precise ratio and correlation coefficient is being obtained. Tape 11 (Davis) is being used as the test case for this new program concept (TPO 360).

B. Stepwise Discriminant Programs (BMDO7M

The BMDO7M programs (or adaptive learning programs) have been applied to our ground spectra for several years at Stanford. The results have been indicative (but not clearly discriminatory) for the several rock types proposed as groups or categories. With the newly redigitised 6B and 7B tape, clear spectra have been obtained and used more successfully in these stepwise discriminant programs. In addition we had an earlier indication from a mistake in processing tape 11, that better discrimination could be achieved with the "raw" spectral emittance data, rather than the subsequently-normalized, spectral emittance ratio data. Accordingly both ideas were tried and the results are summarized below.

1. Tape 6B Emittance versus Emittance Ratio (E RATIO)

A test was made using three training groups of obsidians (15), rhyolite (19) and pumice sands (15), to see if the BMDO7M program could use the discriminant functions optimised on these 3 rock types (unfortunately all very similar) and separate 6 other test categories. In all fairness, this was not a well established test (due to the similarity of the three training rocks), but it did indicate that E-RATIOS are the better data to use.

TABLE V

BMDO7M – STEPWISE DISCRIMINANT PROGRAM
TAPE 6B (rerun 7/19/67)

	6B SPECTRAL EMITTANCE DATA			6B SPECTRAL EMITTANCE RATIO DATA		
GROUP	OBSIDIAN	RHYOLITE	PUMICE	OBSIDIAN	RHYOLITE	PUMICE
OBSIDIAN	15	0	0	15	0	0 *
RHYOLITE	0	19	0	0	19	0 *
PUMICE	0	2	13	0	0	15 *
GLASSY PUMICE	2	3	4	1	8	0
RHYOLITE - ASSORTED	0	15	9	4	19	1
MONO BASALT	1	0	2	0	0	3
QTZ. MONZONITE	0	5	0	0	3	2
RHYOLITE GRAVEL	0	7	0	0	0	7
ODD SPECTRA (FIRTREES + VERMICULITE)	5	2	2	3	4	2

* Plots of the data "clouds" are much more compact with the E-RATIO data, and there are no mis-identification errors. Forty-five spectral points were used in each case, rather than 25 points in all previous analyses.

2. Tape 7B - Effect of airpath length versus time sequence of spectra

Tape 7B has some very interesting spectra (recorded from path lengths as long as 17000 feet to as short as 3 feet), all being taken on the same day, but at two geographically different sites. Again, the analysis is not too clear as the rock at Olmstead Point (called a granite) is not very different in physical or chemical aspects from that at Lembert Dome (called a quartz monzonite).

Modal Analyses (1500 point count, 1 thin section)

	Olmstead Point "Granite"	Lembert Dome Q. Monzonite (equivalent to #316 and #312USGS) (#312)	(#316)
Quartz	29.5%	24.2	25%
K-spar	26.7	27.7	36
Plagioclase	36.2	38.9	40
Amphibole	0.7	0.9	
Mica	4.5	6.9	5
Opaques	2.2	1.4	
	100.0%	100.0%	100%
Color Index	7.4	9.2	

TABLE VIA

SUCCESS RATE WITH AIR PATH LENGTH

OLMSTEAD POINT TPOPO1 ("Granite")				LEMBERT DOME TPLDO1 ("Q. Monzonite")			
TAPE NO.	DATA LENGTH	CORRECT "granite" answer	WRONG "q. monz" answer	TAPE NO.	PATH LENGTH	CORRECT "q. monz" answer	WRONG "granite" answer
711	50'	1	2	718	58'	5	--
712	50'	1	3	719	60'	4	--
713	60'	-	2	720	60'	6	--
710	150'	1	1	721	300'	3	2
709	300'	6	-	722	500'	4	4
				723	500'	1	4
706	2000'	-	9	724	500'	2	2
				725	500'	-	3
705	3000'	1	10	726	650'	-	4
703	3000'	8	-	727	900'	-	1
704	4000'	7	2				
708	17000'	7	2				
714	17000'	1	1				

TABLE VI-B

SUCCESS RATE WITH TIME SEQUENCE OF SPECTRA

TAPE NO.	NOISE TYPE	CORRECT "granite" answer	WRONG "q. monz." answer	TAPE NO.	NOISE TYPE	CORRECT "q. monz." answer	WRONG "granite" answer
703	N	8	-	718	N	5	-
704	N	8	-	719	N	4	-
705	VN	1	10	720	N	6	-
706	VN	-	9	721	N	3	2
708	VN	7	2	722	N	4	4
709	PN	6	-	723	VN	1	4
710	PN	1	1	724	VN	2	2
711	PN	1	2	725	VN	-	3
712	N	1	3	726	VN	-	4
713	N	-	2	727	VN	-	1
714	VN	1	1				

PN = partly noisy
N = noisy

VN = very noisy
(see SRSL Tech Report 67-2)

Table VI- A does not clearly show any degradation of success rate with air path length for the Olmstead Point data but table VI-B indicates the previously established correlation of failure with time sequence of spectra (i.e., lapsed time since helium was added to the detector). Increased lapse time leads to very noisy spectra which correlate wrongly with memory.

This pattern is repeated and confirmed with the Lembert Dome data.

V. METEOROLOGY

A. General Discussion of Need

The atmospheric path through which infrared radiation must pass from a rock source to a spectrometer or radiometer causes a considerable attenuation of the signal. It is more marked at particular wavelengths wherein the atmospheric gases have their principal absorption (water vapor, at 1.138μ, 6.5μ; carbon dioxide at 4.3μ (and at 15.0μ), but never should be entirely dismissed. At any wavelength the atmosphere has a certain amount of attenuation which is primarily a scattering phenomena due to aerosols and dust particles in the path of radiation.

Analysis of Mission 56 aircraft data (as distinct from ground spectral data) has shown a rapid oscillation in the signal received by the airborne instruments. There are three main differences between a ground operation and an aircraft operation:

1. The increased airpath.
2. The changing target (or source) of the infrared radiation beneath the aircraft as a function of its flight.
3. Aircraft vibration effects.

We have shown on long horizontal path spectral studies, (such as those at Tioga Pass over a 17,000 ft path) that the atmosphere does not show a great amount of oscillation of the signal during the 10-second to 60-second recording period. The radiometer for example does not show rapid oscillations of more than approximately 10% of its radiance signal. On the other hand the airborne spectrometers show a considerable change during the short period in which their signals are recorded (150 milliseconds per spectrum). Unfortunately it is not yet clear whether this is (a) due to changing temperatures of the source rocks underneath the aircraft (which must be extremely different to cause the rapid oscillations of the signals seen in the aircraft), or (b) whether this is due to spatial changes (e.g., crossing Benard cells) in the absorption effects of the atmosphere, or (c) due to the more rapid response characteristics of the airborne detector-amplifier system.

We have been working together with the University of Nevada on a meteorological study to assess the spatial and temporal variations of water vapor in the atmosphere in and around the test sites during aircraft operations. The data are as yet not fully reduced, but by the use of radiosonde balloons up to aircraft altitudes (before and after each flight) it is possible to determine (for these two periods of time during operations) what is the distribution of water vapor and air temperatures between the aircraft altitude and the source rocks. Much more work needs to be done to establish the level of accuracy of measurements which are required. It seems that the infrared spectrometers on board the aircraft provide potentially much more definitive measures of the water vapor in the atmosphere than the radiosondes or other hygrometry instruments being utilized on the surface of the ground. It was for this very reason that the low wavelength end of the filter wheel in the P3A instrument was chosen to be in the vicinity of 6.7μ so that the "wings" of the water vapor band could be used to establish the amount of water vapor in the attenuating column. Unfortunately we cannot yet calibrate this sensitive measure as we have had only 2 days of partially successful aircraft operation in the past year.

B. University of Nevada Hygrometry References

A. References on Improved Infrared Absorption Hygrometer:

1. Foskett, L.W. and N.B. Foster, 1943. A Spectroscopic Hygrometer. Bull. Am. Meteorological Soc. 24:146.
2. Wang, J.Y. 1963. Instrumentation and Observation. In: Agricultural Meteorology. Pacemaker Press, Milwaukee, Wisconsin, p. 189-260.
3. Wood, R.C., 1958. Improved infrared absorption spectra hygrometer. Rev. Sci. Instr. 29(1): 36-42.
4. Wood, R.C. 1959. The infrared hygrometer as a potential meteorological aid. Bull. Am. Meteorol. Soc. 40:280-84.

B. <u>Simple Equations for the Computation of Humidity Parameters:</u>

1. e = partial pressure of water vapor (mb)

   e_s = saturation water vapor pressure (mb)

   r = relative humidity (ratio)

   ρ_w = absolute humidity, or water vapor density (g cm^{-3})

   q = specific humidity (g kg^{-1})

   w = mixing ratio (g kg^{-1})

   d = saturation water vapor deficit (mb)

   T_d = dew point temperature (°C)

   T = air temperature (°K)

   P = atmospheric pressure (mb)

   T_w = wet bulb temperature (°C)

C. 2. Equations for humidity parameters:

$$r = e/e_s$$

$$\rho_w = 2.165 \times 15^7 \quad e/T$$

$$q = 622 \ e/p$$

$$w = 622 \ e/(p-e)$$

$$d = e_s - e = e_s(1-r)$$

T_d can be obtained from Table.

T_w can be obtained from Table.

Meteorological Instrument Shelter

by Steve A. Samon, Graduate Student

The purpose of the meteorological instrument shelter is to enable the trained observer to obtain data that is a true representation of the air mass being sampled. If one attempts to measure the temperature of the atmosphere by placing the thermometer in a location that affords no protection from direct solar radiation, the reading obtained will be erroneous and of no value to the observer. For this reason, it is important that the instruments are placed so that no incident or direct radiation falls upon them. The most widely used method for obtaining true readings is the instrument shelter. With the use of a meteorological instrument shelter, the instruments contained therein are able to assume the temperature or humidity of the air mass being sampled.

The Stanford Instrument Shelter is a modified type of that in current use by the United States Weather Bureau. The shelter has a double roof with louvered sides. The bottom of the shelter has holes in it for ventilation of a convectional type. The Stanford shelter has been designed for field use in that it is completely portable and can be broken down into a small package for transit to remote sites. The bottom and top of the shelter have mounting brackets designed to accommodate auxillary equipment such as the ISCO radiometer and the Sol-a-meter. When properly set up the entire weather station can be placed either in or upon the shelter so as to eliminate movement between instruments while taking data. The location and height above ground of the shelter is just as important as the type of construction. If a instrument shelter is not located at the proper height above ground, the data may not be a true indication of the air mass conditions. The shelter should be located at a minimum of 4 feet above a large, flat surface, preferably grassy, and at least 10 feet away from buildings or other vertical surfaces. When the shelter cannot be mounted above a grassy surface, there should be a wooden grate between the surface and the floor of the shelter. The shelter faces north in the Northern Hemisphere and south in the Southern Hemisphere so that the sun will never shine directly on the instruments in the shelter when the door is opened. The instrument shelter should be kept free of dirt and dust both inside and outside at all times. Keep the paint clean to insure maximum efficiency of the shelter in affording protection of the instruments from radiation and conduction of heat from outside sources. Free water surfaces in the instrument shelter will adversely affect the instrument readings and result is nonrepresentative observations. The most important meteorological data in regards to infrared sensing is the amount of water vapor in the atmosphere at the time of observation.

The effects of the earth's atmosphere must be seriously considered in the design and use of infrared sensing equipments. The infrared radiation incident on a receiver is always extensively changed by the atmosphere intervening between it and the target. This intervening medium is an inhomogeneous and continuously changing mixture of gases, liquid droplets, and particulate solid matter. The gases of primary interest are water vapor (H_2O), Carbon dioxide (CO_2), nitrous oxide (N_2O), and ozone (O_3). These gases will absorb and emit radiation as a function, among other things, of the number of molecules present, the wavelength involved and the energy states of the molecules. The prediction of scattering effects is made difficult by the fact that the applicable Mie scattering theories require knowledge of particle numbers, densities, shapes, sizes, and electrical characteristics which depend on the materials that make up the particles. These parameters are not easily determined, and the theory cannot take all of the factors into account unless many simplifying assumptions are made. The transmitted radiation is also subject to refraction by the medium traversed. Absorption, emission, scattering, and refraction all vary with time and space throughout the path of transmission. The constant motion of the atmosphere, on both micro- and macroscopic scales, create these variations in as unpredictable a pattern as the variation in other meteorological parameters. Only on a statistical basis is any prediction possible.

From the foregoing information, one can see how important accurate meteorological data is in the field of infrared sensing. With the meteorological instrument shelter, we hope to eliminate one more variable parameter in regards to the collection of ground truth data.

VI. MAJOR EQUIPMENT STATUS

A. Laboratory and Field Recording Equipment

1. Digital Recording System

A digital data recording system is being constructed at Stanford which will a) record field directly onto IBM 360 compatible digital tape and b) serve as a model system for the design of aircraft and spacecraft data systems.

The computerprograms to handle data from this system are already in operation and are highly successful on P3A aircraft data of the same type, proving to be even cheaper to run than predicted.

The hardware to convert field data is about 75% complete. The encoder is installed on the SG-4 wavelength drive and positive wavelength assignments are finally possible. The items as yet incomplete are the interface between A – D converter and the tape unit, and multiplex unit to enable Huggins radiometer data to be included as well within each physical record. The spectrometer is sampled at 90 samples/spectrum triggered by the encoder pulses in order to be compatible with the data output format presently being used for the NASA P3A aircraft system.

The Stanford digital system will also be directly compatible with the filterwheel spectrometer (CVF) being constructed here, as well as the SG-4 spectrometer, but the CVF concept will allow some simplification of the SG-4 logic.

B. Laboratory and Field Equipment

1. SG-4 Spectrometer

The SG-4 spectrometer is working satisfactorily and can produce good quality spectra of unpolished samples with a reasonable degree of repeatability. We have departed from the practice of using liquid nitrogen in the reference dewar and are learning how to choose the reference temperature to produce the best spectra from a given batch of samples by emphasizing the spectral departures from a blackbody. The instrument still retains two original design features which are undesirable however;

a) The viewfinder and the optical axis do not appear to be in line, or even out of alignment by a constant amount, and attempts to correct this have been unsuccessful.

b) The "up-" and "down-"ramp spectra consistently show differences in wavelength and amplitude. While this too we cannot explain, we are using a present solution of treating the two types of spectra independently in the computer.

Apart from completing the data system no work on the actual SG-4 spectrometer is necessary right now. Without considerable financial outlay item b is uncorrectable. Optical re-alignment will be attempted at the same time as for the CVF unit.

Spectra of approximately 50 rock samples were run this summer.

2. CVF Spectrometer

In-house work on the new instrument stopped some months ago due to the pressure of impending aircraft and field schedules, and now, recently, by the need to complete data reduction of a tape backlog. Apart from optical alignment, no further work on this instrument will be scheduled until the new year.

The CVF spectrometer has operated successfully in the laboratory during initial tests, taking 30 seconds to produce a "clean" 7-14μ spectrum of room temperature samples, using a 0°C reference. The instrument now needs:

a. Packaging
b. Installation of encoder.
c. Installation of in-line viewfinder.
d. Possible installation of miniature pre-amplifier. (At present not considered necessary.)
e. Optical alignment.
f. Installation of blackbody temperature controller.

B. Field Equipment

Barnes IT3 Radiometer

The IT3 has been used extensively in field work supporting the CV240 flights (MX 55, 56, 59) and is still functioning correctly despite its design as a lab rather than a field unit. It has developed an error of about 2°C on all readings after a bad fall following Mission 59.

A new low power inverter has been built into one end of the unit to increase portability by enabling the IT3 to be run off either 115 V A.C. or a 28V Ni-Cd battery pack. In this portable mode, it operated for 2-3 hours during a recent Stanford overflight. It has not been tested to find what is the maximum life of the battery pack.

Huggins Mark IX Radiometer

This instrument has never functioned satisfactorily despite repeated trouble shooting, and other repairs by the manufacturer. Its present accuracy is more of an unknown quantity than before. We propose to perform a series of sensitivity tests on the instrument to determine whether we should spend some funds in upgrading the radiometer, or whether the instrument should be replaced altogether.

VII. TRAVEL

Travel on this project has been restricted to field work. Charges for trips to Houston since July 1, 1967 concerned with the P3A instrumentation and scheduling have been charged to the Houston contract NAS9-7313. The following travel for ground spectra operations has been performed.

Field		
Reno Nevada	2 man days	Planning of Mission 55/56 with site inspection
Tioga-Reno-Mt. Lassen	20 man days	Mission 55 and Microwave meeting (Tape 21 in field)

VIII. FISCAL DETAILS

A breakdown of the fiscal expenditures to date has been included for the 24 month period up to 10/31/67. It should be realized that the total expenditures indicated are higher than actual in that there are still remaining several wrongly assigned charges which would be removed from this account. Personnel salaries have been corrected to reflect these changes but have not yet appeared on the output from the computer sheets with the budget summaries. The allocation of effort by the various personnel is corrected to show these changes but the fiscal structure has not yet been so modified.

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